

Temperature-dependent Vacancy Formation during the Homoepitaxial Growth on Cu(001)

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Beamline(s): X3B2

X-ray scattering has been used to study kinetic roughening of the Cu(001) surface during homoepitaxial growth at low temperatures. When the temperature of the substrate was lowered below 160K, qualitative changes of the growth were observed. This is demonstrated in Fig.1, which shows the effect of reducing the temperature from 160 to 110K on the reflectivity from Cu(001) with 15ML deposited. At 160K, the reflectivity measured around the (002) Bragg reflection (open circles) is very well described by assuming a simple Gaussian fluctuation of the surface height (solid line in Fig.4.a.). On the other hand, at 110K, the reflectivity lineshape exhibits thin film interference fringes as well as a pronounced asymmetry about the (002) Bragg reflection (Fig.4.b). We find that both of these features arise from the presence of a compressive strain in the deposited film. Indeed, the data at 110K are excellently described by a model where, in addition to considering the surface roughness, we allow the surface-normal interlayer spacings in the film, d_{film} , to differ from their value in the bulk crystal, d_{bulk} . A best fit to

this model (solid line line in Fig4.b.) yields $\frac{d_{film} - d_{bulk}}{d_{bulk}} \approx -1\%$. A strain of a smaller magnitude (-0.4%) leads to

a reflectivity profile (dashed line) that significantly deviates from our data. We believe that the compressive strain is induced by a large vacancy concentration, which is likely to appear in the deposited film when the growth occurs at very low temperatures. By using the linear relationship between the concentration of point defects and the strain in a film we estimate that a ~2% vacancy concentration is present in the Cu film deposited at T=110K. The concentration of the incorporated vacancies, c_v , is temperature-dependent. As shown in Fig.2, it decreases with the increasing temperature from $c_v \sim 2\%$ at T=110K to $c_v \sim 0$ at T=160K.

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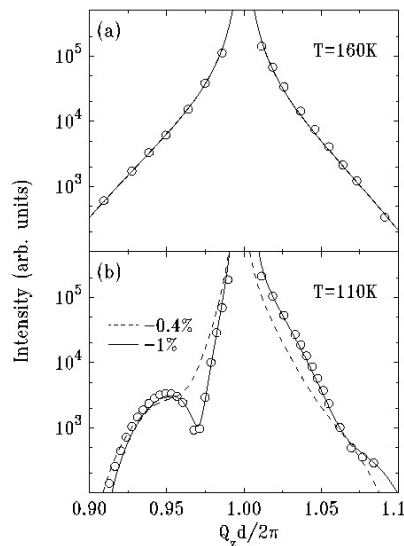


Figure 1. Specular reflectivity from Cu(001) surface, with 15ML deposited at (a) T=160K and (b) T=110K (open symbols). At 160K, the data is well described by a simple Gaussian fluctuation of the surface height (solid line) while, at 110K, a real-space model that includes a large compressive strain in the deposited film is necessary to fit the pronounced asymmetry of the reflectivity. The fit yields 1% for the magnitude of the strain. As shown by the dashed line, a strain of smaller magnitude is not consistent with our data. The strain is induced by a 2% vacancy concentration incorporated in the growing film.

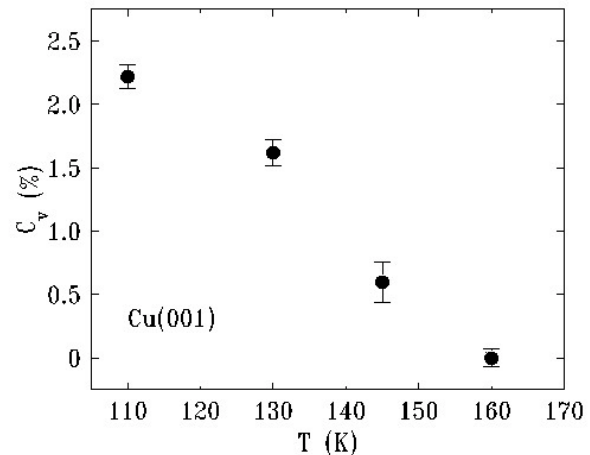


Figure 2. Temperature dependence of the vacancy concentration as it results from fits to x-ray reflectivity data like the one in Fig.1.(b).